Virtual Autonomous Navigation Environment

76th MORS Symposium
10-12 June 2008

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Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE **01 JUN 2008**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Virtual Autonomous Navigation Environment**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Geotechnical and Structures Laboratory**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM202527. Military Operations Research Society Symposium (76th) Held in New London, Connecticut on June 10-12, 2008, The original document contains color images.

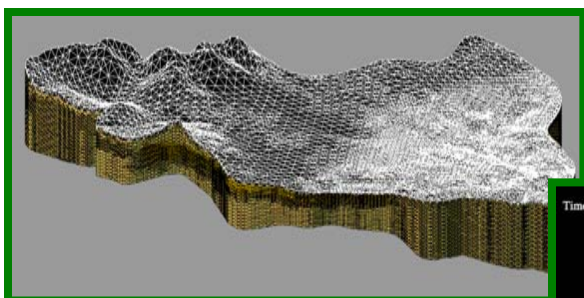
14. ABSTRACT

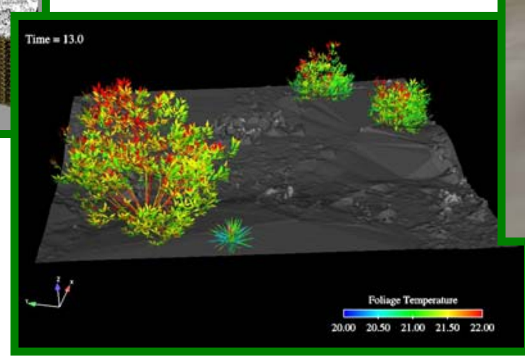
15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**17**	

VANE Research Focus

- **Integrate vehicle mobility, ground physics, terrain physics and sensor response models into a High Performance Computing computational testbed to facilitate virtual testing of UMS for autonomous navigation performance**





VANE Simulation Testbed

Schedule				
Milestones	**FY08**	**FY09**	**FY10**	**FY11**
Mechanical systems				
UI design and construction				
CTB Environment Interface				
JAUS Applications				

Purpose:

- **Represent mechanical system interactions with the CTB**
- **Realistic movement**
- **Provide an interface for mechanical systems and sensor models**
- **Allow easy configuration of mission scenario**

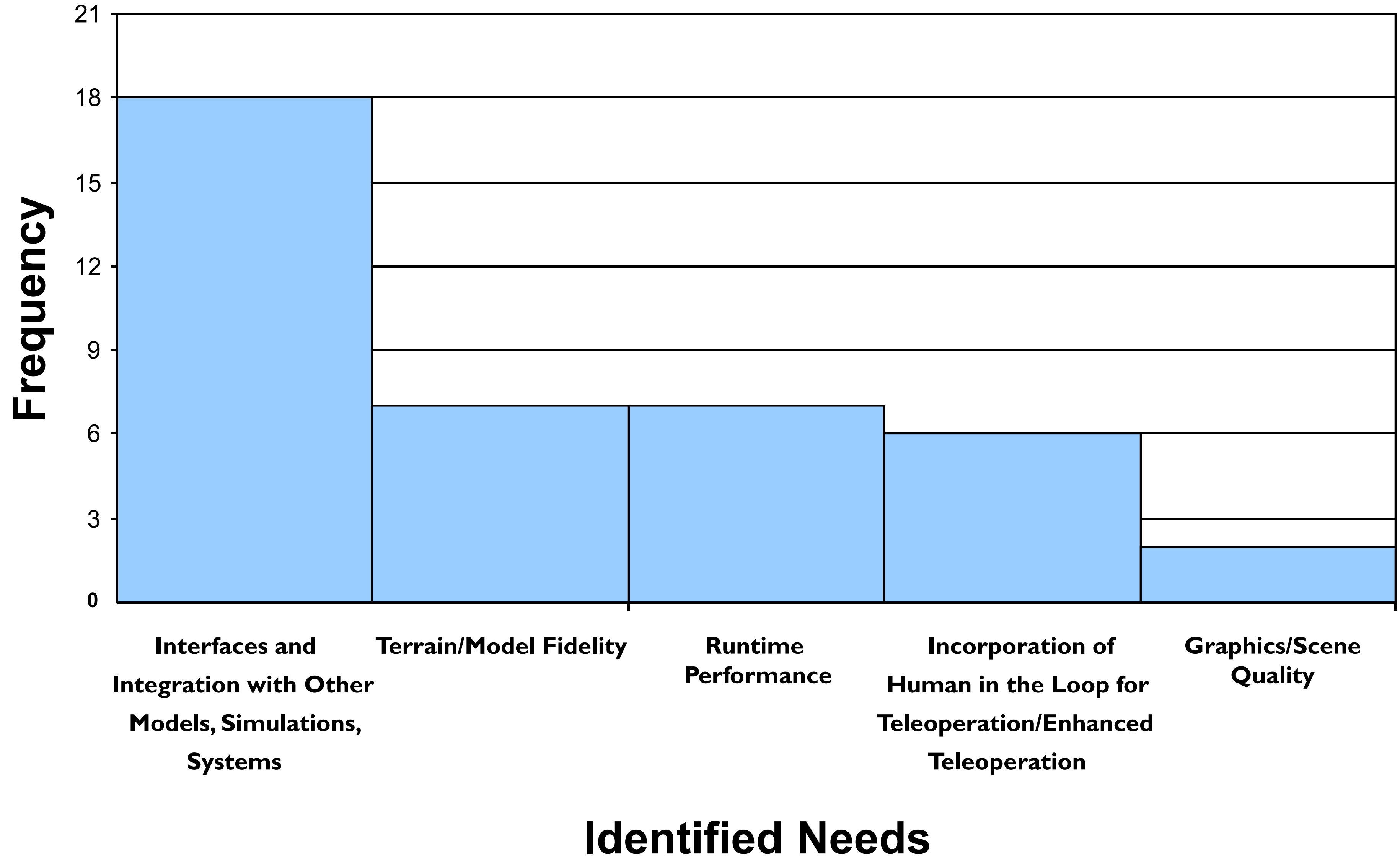
Results:

- **JAUS Compliance**
- **Dynamics engine for VANE simulation**
- **Simultaneous viewing of sensor output, vehicle mobility, and ANS**
- **Mission rehearsal and playback**

Payoff:

- **Interaction with guest JAUS compliant subsystems.**
- **Faster debugging of components**
- **Viewing options for output data**

Major Needs Identified by Stakeholders



Functional Analysis

Objective: Provide a high-fidelity, high-resolution environment for assessment of UGV systems and subsystems across concepts, designs, and operations to achieve implementation of the best systems.

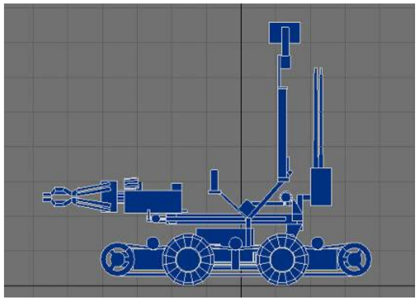
- 1. Provide Interfaces
  - 1.1 Interface to UGV / Component Models
  - 1.2 Interface to Other Virtual Constructive Simulations / Environments
  - 1.3 Interface with Hardware in the Loop
  - 1.4 Interface with Human in the Loop
- 2. Represent Environmental Features and Attributes
  - 2.1 Affect Sense
  - 2.2 Affect Move
  - 2.3 Affect Communicate
- 3. Perform Computations
- 4. Support Experiments and Exercises
  - 4.1 Enable Dynamic Modification
  - 4.2 Collect Data
  - 4.3 Run Batches
- 5. Provide 3D Visualization

Common Open Architecture

- **Open Architecture Characteristics:**
  - Based on Open, Publicly Available Specifications — Preferably Maintained as Standards by a Consensus Process, e.g. By an Internationally Recognized Governing Group
  - Well-defined, Widely Used Non-Proprietary (Standard) Interfaces, Services and Formats
  - Durable (Stable or Slowly Evolving) Component Interfaces That Facilitate Component Replacement and Addition of New Capabilities
  - Upgradeable Through Incorporation of Additional or More Capable Components With Minimal Impact on the System

Vehicle/Object Modeling

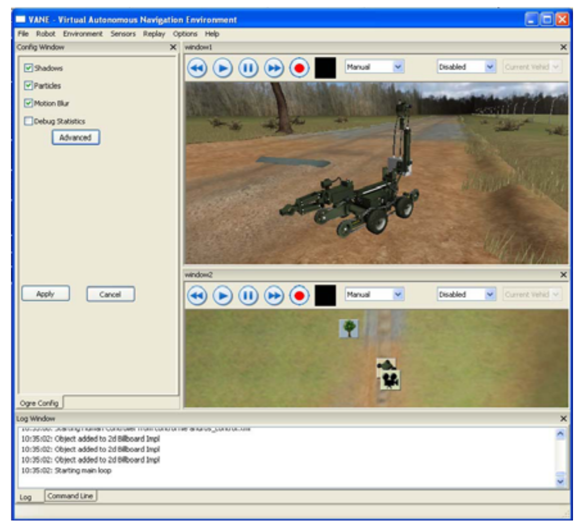
- **Objects exist in several contexts**
  - Collision geometries
  - Joint constraints
  - GUI visualization
  - Sensor detection



- **Every object needs to make sense in each of these contexts.**
- **The testbed manages the objects so that the contexts can be resolved to one entity**
- **Some object data can be manipulated graphically though the testbed.**

GUI Design

- **OGRE rendering engine**
  - **Object Oriented Graphics Rendering Engine**
  - **Open source**
  - **Object Oriented for manageability**
  - **Includes shadow, shaders, object and scene loading, and other functions to reduce programming time.**
  - **Portable**
  - **DirectX/OpenGL**
- **WXWidgets interface**
  - **Free software license**
  - **Powerful**
  - **Easy to program**
  - **Multiple windows**
  - **Portable**
  - **Uses the native GUI to reduce the learning curve**



Ridged Body Dynamics Simulation

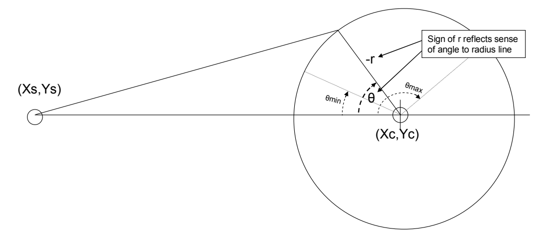
- ODE (Open Dynamics Engine)
  - Open Source
  - Mature
  - Widely used
  - Fast or Accurate
  - Portable

Robot picking an object

- Different levels of accuracy are possible
  - Allows for different uses for the VANE test bed depending on the mission.
- The option exists if replacement of ODE with other physics solutions such as PhysX is desired.
- ODE has an active user base to help in solving programming issues and to ensure continuing updates.

Actuator Modeling

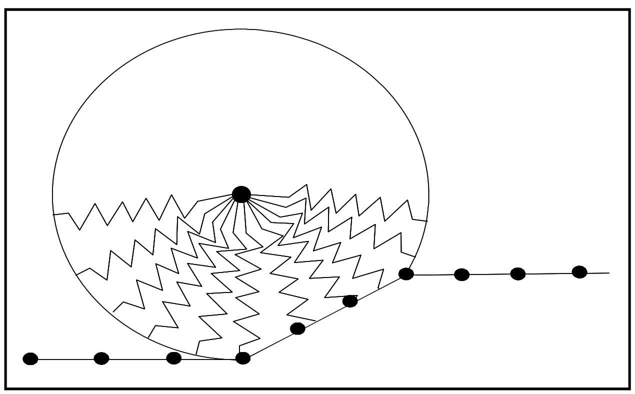
- **Actuator joints and motors**
  - **Linear Actuators**
  - **Rotational Servos**
  - **Lever Arms**
  - **Motors/Engines**



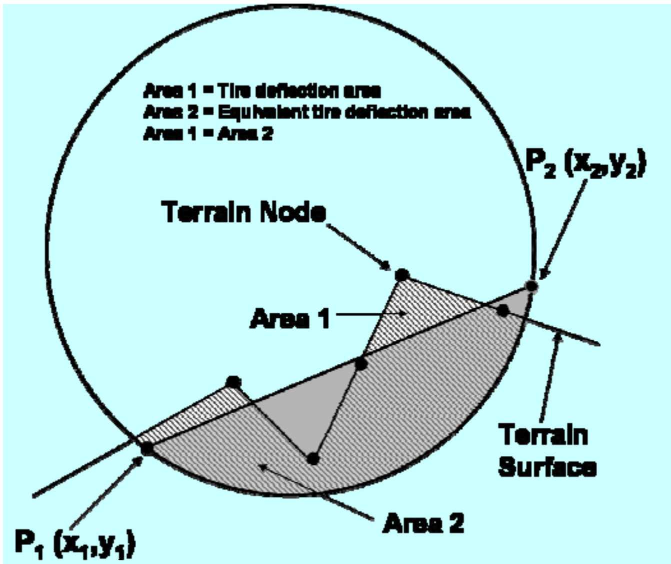
- **The joints use either a force or a speed solver.**
  - **The speed solution is used on joints that are not torque limited. This allows for easy and accurate modeling of speed limited joints.**
- **Lever arm linkages are modeled internally to the actuator to decrease degrees of freedom in the physics solver.**

Ground Contact Interface

- The terrain is represented by a series of nodes
- The forces on the wheel are computed using the continuous spring tire model
- The traction element sinkage is determined and used to calculate the sinkage at the current time step that applies to each terrain node in contact with the traction element



Continuous spring tire model and terrain nodes



$$S_c = (V \times T)/C \times S$$

S = Predicted total sinkage (in) for entire wheel
C = Chord Length (in) from P1 to P2
T = Time step (sec)
V = Vehicle's instantaneous velocity (in/sec)
S_c = Sinkage (in) this time step

Terrain Generation

- **Conversion to formats appropriate to dynamics and visualization**
  - **High resolution for dynamics modeling**
  - **Low resolution for GUI display**
- **The Terrain formats allow for paging of large data sets.**
- **The formats also allow for easy deformation of the terrain by the soil sinkage models.**

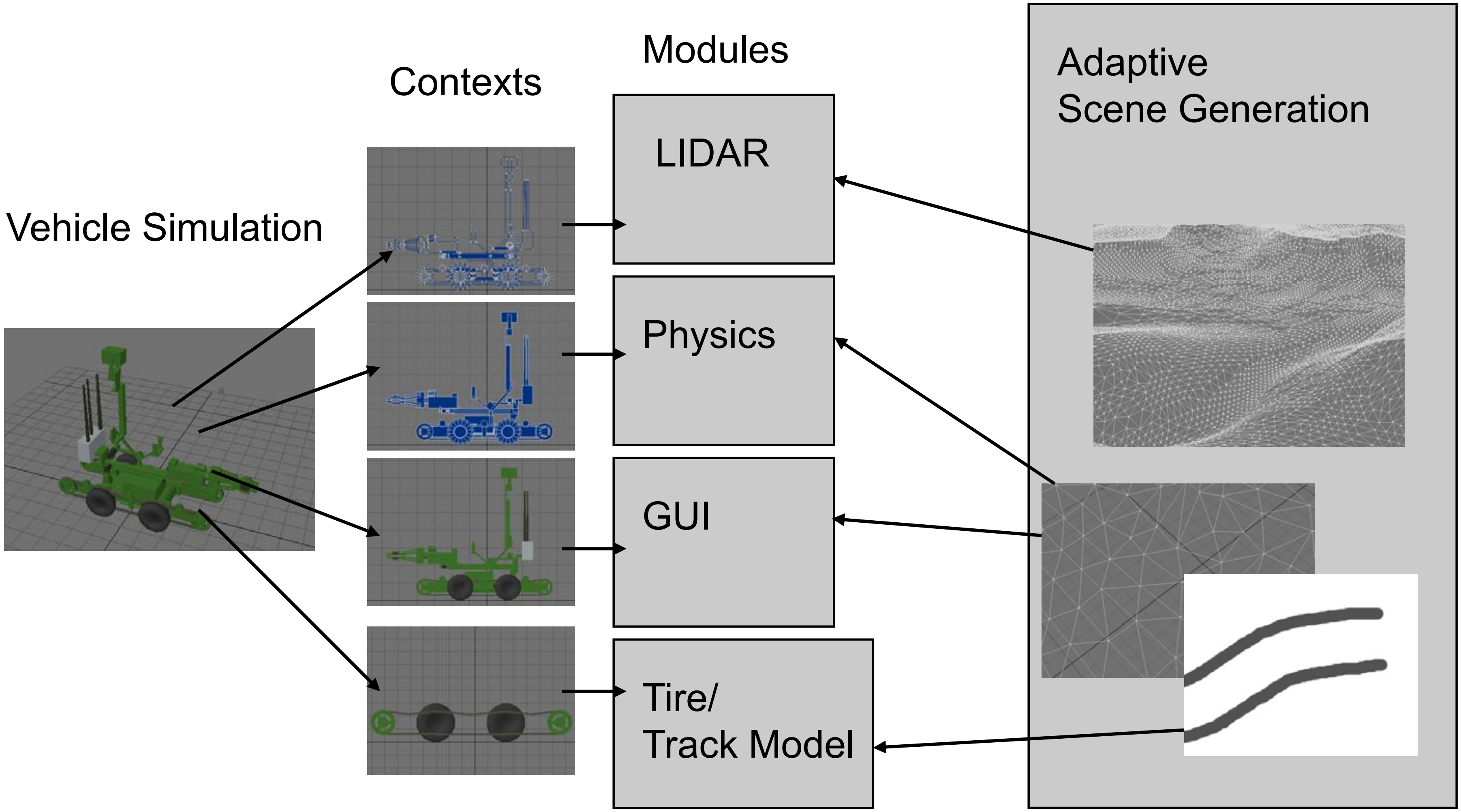
Simulated and Real Environments

Operating over scanned terrain

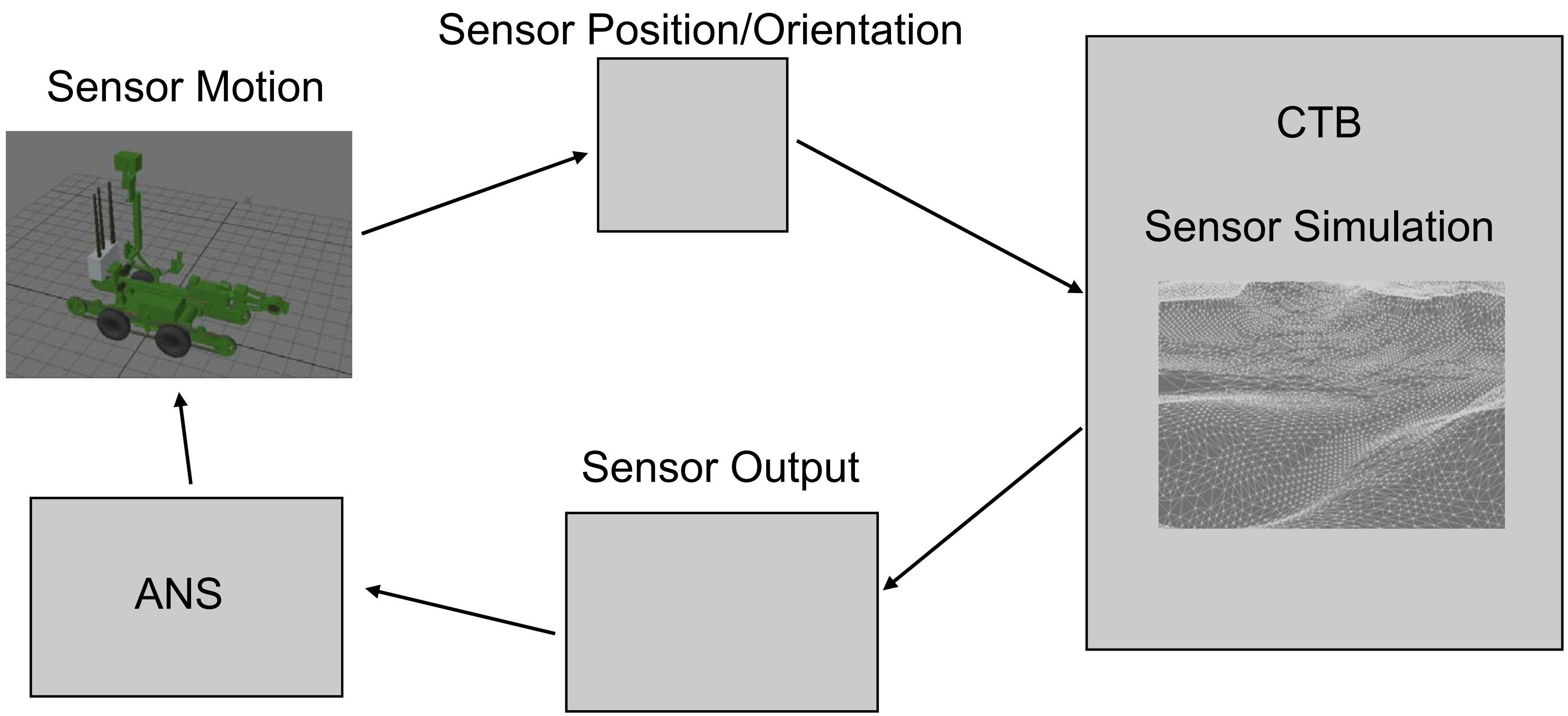
Path Forward

- Operator Control Unit (OCU) construction
- Interaction between sensor models and vehicle simulation
- Easier integration of terrain into dynamics engine
- Importing of larger data sets

Testbed / CTB interaction



Testbed / CTB interaction



VANE Simulation Testbed

- **Demonstration of the VANE Dynamics**